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A Three-Layer Model to share emotional information

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Abstract *In this study, we present a generic solution of emotional data exchange between heterogeneous multi-modal applications. This proposal is based on a new algebraic representation of emotions and is composed of three distinct layers : the psychological layer, the formal computational layer and the language layer. The First layer represents the psychological theory adopted in our approach. The second layer is a formal multidimensional model that matches the psychological approach of the first layer. In the language layer, we propose to extend the current implementation of EmotionML [1] to generate the final emotional data to be transferred through the network. We propose to modify the EmotionML vocabulary in order to represent emotions in our vector model defined in the formal computational layer.*

1 Introduction

Human emotions are becoming a crucial aspect in human-machine interactive systems. Indeed, affective computing expands human-computer interaction by adapting the experience to the emotional state of the user. There is a rising need for emotional state recognition in several domains, such as health monitoring, video games and human-computer interaction. The emotional information exchange between applications entails many problems such as application heterogeneity, complexity of emotional states, diversification of capture tools and dependence between treatment and physical sensors. The lack of a standard in human emotions modeling hinders the sharing of affective information between applications. As part of the research project Emotica, we aim at defining a formal model allowing the communication between various multi-modal applications. In our work, we are interested in the 3D video games especially serious games like flight simulators. In this type of games we are very interested to

know at each instant the felt emotion by the player and to adapt in consequence the simulation. We target also to transfer the emotional data between the various players using different platforms and modalities.

In this paper we propose a generic computational model for the representation and exchange of emotional states and for a better multi-modal analysis. Our proposal is composed of three distinct layers: the psychological layer, the formal computational layer and the language layer. In this paper, we explain the role of each layer of our generic model and their relationships to each other. The remainder of this paper is organized as follows. In Section 2, we give some related psychological and linguistic theories of emotion. In Section 3, we describe the different layers of our model and we conclude in Section 4.

2 Related Work

There is no consensus among psychological and linguistic theories on emotions. The word "emotion" comes from the Latin "emovere, emotum", which means movement towards the outside. Emotion is a complex concept. Darwin [2] thought emotions to be innate, universal and communicative qualities. Ekman [3], Plutchik [4] and MacLean [5] have developed the theory that there is a small set of basic Emotions emotions all others are compounded. The most famous of these basic emotions are the Big Six, used in Paul Ekman's research on multi-cultural recognition of emotional expressions [6].

Representing emotional states in technological environments is necessarily based on some representation format. Ball and Breese [7] have proposed a model of emotional states based on the Bayesian networks, which is designed to estimate the emotional state of a user interacting with a conversational compute. López et al [8] have proposed a model based on a generic ontology for describing emotions and their detection and expression systems taking contextual and multimodal elements into account. In earlier work [9] we have proposed an algebraic model for the representation and the exchange of emotions. Our model permits to model not only the

basic emotions (e.g., anger, sadness, fear) but also different types of complex emotions like simulated and masked emotions.

3 The proposed model

Our proposal consists on a Three-Layer Model to share emotional information. As its name implies it is composed of three distinct layers which are interdependent to ensure a maintenance of coherence of the model: the psychological layer, the formal representation layer and the language layer.

3.1 The First layer: The psychological layer

The psychological layer represents the psychological theory adopted in our approach which is the Plutchik's theory. Indeed Plutchik model consists on a three-dimensional "circumplex model" which describes the relationships between emotions. He argued for eight primary emotion arranged as four pairs of opposites: (Joy-Sadness, Fear-Anger, Surprise-Anticipation, Disgust-Trust) [4]. He suggested that non basic emotions are obtained through the addition of basic emotions (color analogy, Plutchik, 1962) [4]. In his model, for instance, Love = Joy + trust and Delight = Surprise + Joy. Plutchik defined rules for building complex emotions out of basic ones. In practice, combination of emotions follows the method "dyads and triads" [4]. In our work, we chose the Plutchik model to represent the psychological layer because it verifies many important conditions for the elaboration of our model and it explains emotions in terms of formulas that can be universally applied to all human beings. First, the Plutchik model is based on 8 basic emotions encompassing the common five basic emotions. Then, it takes into account the intensity of emotion i.e., the level of arousal or the feeling degree of each basic emotion for example (terror, fear, apprehension). Finally, the Plutchik model is intuitive, very rich and it is the most complete model in literature because it permits to model complex emotions by using basic ones.

3.2 The second layer: The formal computational layer

The formal computational layer matches the psychological approach of the first layer. It is the formal representation of Plutchik's model and it is based on an algebraic representation using multidimensional vectors. We represent every emotion as a vector in a space of 8 dimensions where every axis represents a basic emotion defined on the Plutchik theory. We defined our base by $(B) = (\text{joy}, \text{sadness}, \text{trust}, \text{disgust}, \text{fear}, \text{anger}, \text{Surprise}, \text{anticipation})$. Thus, every emotion (e) can be expressed as a finite sum (called linear combination) of the basic elements.

$$(e) = \sum_{i=1}^8 \langle E, u_i \rangle u_i \quad (1)$$

$$\text{Thus, } (e) = \alpha_1 \text{ joy} + \alpha_2 \text{ sadness} + \alpha_3 \text{ trust} + \dots \\ + \alpha_7 \text{ surprise} + \alpha_8 \text{ anticipati}$$

Where α_i are scalars and $u_i (i=1..8)$ elements of the basis (B) . Typically, the coordinates are represented as elements of a column vector $E = (\alpha_1, \alpha_2, \dots, \alpha_8)$ Where $\alpha_i \in [0;1]$ represents the intensity of the respective basic emotion. More the value of α_i get nearer to 1, more the emotion is felt.

According to the Plutchik's theory, the mixture of pairs of basic emotions resulted of complex emotion. Joy and trust for example produce the complex emotion "love". "Submission" is a mixture of trust and fear. We defined the combination between emotions as the sum of two emotion vectors [9]. This addition is defined as the maximum value of coefficients for the same emotion. For the same axis, we keep the highest one because each modality can detect better a specific emotion. For example with the heart rate modality we can detect the fear component better than the facial expression modality.

The multidimensional representation of the formal computational layer provides the representation of an infinity of emotions and provides also a powerful mathematical tools for the analysis and the processing of these emotions. Indeed we can apply others usual basic

algebraic operations on vectors like the scalar multiplication, the projection and the distance in an Euclidean space. for more detail you can see [10].

3.3 The language layer

The third layer of our model is the language layer. This layer provides encoding emotional information. We propose to use the Emotion Markup Language (EmotionML) for describing emotions. In fact, EmotionML provides representations of emotions and related states for technological applications. Given the lack of agreement in the community, EmotionML does not provide a single vocabulary of emotion terms, but gives users a choice to select the most suitable emotion vocabulary in their annotations. In our work, we propose to introduce in EmotionML a new element `<plutchik-dimension>` in order to represent emotions in our vector model defined in the formal computational layer. Therefore, we suggest to modify the EmotionML vocabulary and introduce the following item (It consists of a `<vocabulary>` element containing a number of `<item>` element) :

```
<vocabulary type="plutchik-dimension" id="intensity-dimension">
  <item name="joy"/>
  <item name="sadness"/>
  <item name="trust"/>
  <item name="disgust"/><item name="fear"/>
  <item name="anger"/>
  <item name="surprise"/>
  <item name="anticipation"/>
</vocabulary>
```

The next example was generated using both face and voice modalities. Each modality gives a vector with different coefficients. Using the vector addition of the computational layer, we obtain the final vector describing the felt emotion

```
<emotionml xmlns="http://www.w3.org/2009/10/emotionml">
  <plutchik-dimension-set="http://www.w3.org/TR/emotion-voc/xml#intensitydimension">
    <emotion expressed-through="face physiology">
      <plutchik-dimension name="joie" value="0.8" />
      <plutchik-dimension name="sadness" value="0.2" />
      <plutchik-dimension name="trust" value="0" />
      <plutchik-dimension name="disgust" value="0" />
      <plutchik-dimension name="fear" value="0" />
      <plutchik-dimension name="anger" value="0.7" />
      <plutchik-dimension name="surprise" value="0" />
    </emotion>
  </plutchik-dimension-set>
</emotionml>
```

```
<plutchik-dimension name="anticipation" value="0" />
</emotion>
</emotionml>
```

4 Conclusion

In this paper, we proposed a generic model facilitating communication between heterogeneous multi-modal applications. Our model is based on psychology research. It is composed of three distinct layers where each layer provides services that higher-level layers depend on. The middle layer provides powerful mathematical tools for the analysis and the processing of emotions. We introduce the implementation of EmotionML in the third layer and explain how it is used to represent and transfer emotional information between heterogeneous applications. We proposed to extend the current implementation of EmotionML to represent emotions in terms of our vectorial model defined in the middle layer.

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